each actuator to drive multiple stimulus points **17**. **FIG. 8** illustrates rotational scanning wherein the outputs at **60** from each actuator or drive is received at rotational scanning device **61** which directs the output (e.g., flow of pressurized working fluid) to each of a number of output lines **63** in sequence. The outputs at lines **63** are directed to individual stimulus points **17**. If desired, all of the rotational devices **61** can be mounted on a common driving shaft turned by one motor. For this and the other scanning methods herein, the timing of the signals from the actuators must take into account the propagation delay to array **15**, so that the stimulus signals are delivered to the correct points **17** and thus to the correct points at the user's body.

[**0064**] A one-dimensional array **65** of actuators **67** is shown in **FIGS. 9 through 11**. Actuator array **65** is coupled to columns **69** of stimulus points **17** of display array **15** and a second set of actuators **71** is provided to select rows **73** of stimulus points **17** of display array **15** one at a time, so that the actuators together operatively transfer signals (air pressure, for example) to the various stimulus points **17** of display array **15** one row **73** at a time. As shown in FIGS. **10** (wherein a row **73** is selected by an actuator **71**) and **11** (wherein a row **73** is deselected by an actuator **71**), for the case wherein each column actuator **67** controls flow of working fluid, actuators **71** turn on valve assemblies **75** serially thereby connecting the column actuators to each row in turn.

[**0065**] As another alternative, the outputs of the actuators could be coupled (using flexible links) to a device that scans back and forth across a two-dimensional array in order to drive all the stimulus points. The scanning device could use rigid pins (like the pins of a dot matrix printer head) to impact the stimulus array points **17** directly, or energy transfer can take place at mechanical transducers for activation via flow of a working fluid.

[**0066**] Since the tactile display apparatus of this invention are intended to provide a user with a realistic impression of a virtual object (which may or may not represent a real physical object), there are applications for which it is worthwhile to increase the sense of reality by providing additional cues to the senses of the user. In addition to the detailed tactile stimulus provided by array **15**, and (if the application is a virtual reality or augmented reality system) the possible force feedback of a haptic system plus any visual or audio cues that may be present, other sensory inputs are utilizable with the apparatus of this invention. For example, application of lateral pressure to the fingertips or other body location can be supplied at array **15** to apply lateral force in selected direction to replicate the sensation of speed of movement over a surface, force of fingers against an object and/or the sensed friction of movement of the finger over a real object. Since real objects may be warmer or cooler than a fingertip or other body location, and may have different levels of latent heat and thermal conductivity, a simple thermal addition to the display apparatus of this invention may use heating or cooling to set the surface of display array to a specified temperature. A more sophisticated system may more closely replicate the thermal properties of various substances by regulating the flow of heat into or out of the fingertip at array **15** as different virtual articles or environments are displayed.

[**0067**] In tactile graphic design there is a tradeoff between complexity of implementation and realism. Improved realism (making the experience using the display more like a real-life experience) may be desirable and (as heretofore suggested) implementable, but it is not necessary to have perfect realism for a display to be quite usable for most applications. Safety of such systems is also an issue. Most users will not want to actually be injured if the display apparatus is attempting to reproduce a pinprick. Designers may impose limits on the amount of force that a tactile graphic display stimulus point **17** may apply, on the "sharpness" of the application of force (the small-area differential in force applied to the skin), and possibly the magnitude, frequency and duration of vibrations applied to the skin. One factor that may influence designers is that reducing the magnitude of the forces applied to the skin by the display reduces the impact of the safety issues while also reducing cost of construction and operation.

[**0068**] When a fingertip display array **15** is integrated into a data glove **23** with force feedback, the forces applied to the skin by array **15** are superimposed over the forces applied by the haptic system. In a real world situation, the detailed textural information picked up by the finger may be thought of as a differential pressure signal that is proportional to the total pressure being applied to the skin. It will therefore increase the realism of the combined tactile/haptic system if the differential pressure applied by the tactile display array **15** is made to increase when the pressure applied by the haptic system increases. In the real world this would be a linear relationship. In a display system of this invention, the maximum pressure that can be applied by the tactile display may be considerably less than the maximum pressure that can be applied by the haptic system, so some other mapping function of haptic system force to tactile system pressure may be needed. For example, the relation may be linear at low force levels, then taper off toward the point at which the tactile display is exerting maximum differential pressure. Another approach is to keep the relationship linear until the tactile display reaches maximum output, then to keep the differential constant from that point on. Either approach can provide sufficient realism to make the tactile/haptic system useful. It should be noted that the pressure-based tactile display apparatus of this invention can achieve adjustment of the differential pressure either by modulation of the fluid flow to the individual stimulus points **17**, by varying the pressure of the fluid to modulator **29**, or a combination of both. The ability to vary the pressure of the fluid to the modulator may be particularly useful because it is adjusted for the entire localized body area in contact with array **15** in much the same way that the force to the body area by the haptic system is applied, and because it will not interfere with the modulator's ability to provide a wide range of forces to individual stimulus points **17**.

[**0069**] Another design factor for data glove **23** applications is the thickness of the display structure. If the user initiates a motion that would bring two fingertips together (for example), then the thickness of the display limits the proximity of the two fingertips. Thus the display (i.e., matrix/stimulus points combination) should be as thin as possible and likely will require placement of modulator **29** remote from display array **15**. Use of a multiplexing mechanism at the output from modulator **29** will permit a reduction in the number of fluid channels **27** from a remotely positioned modulator to array **15**. Positional details of relative spacing between two opposed fingertips might be more important than absolute spacing provided that absolute spac-